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CORRESPONDENCE CHART

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- 10 REFLECTIVE LCD ARRAY
- 10a ALTERNATE EMBODIMENT OF REFLECTIVE LCD ARRAY
- 10b ALTERNATE EMBODIMENT OF REFLECTIVE LCD ARRAY
- 12 METAL LAYER
- 10 14 MIRRORS
- 16 VIAS
- 18 INSULATING LAYER
- 19 ADDITIONAL METAL LAYERS
- 20 CLEAR PROTECTIVE LAYER
- 22 PIXEL SPACING
- 22a ALTERNATE PIXEL SPACING
- 24 MIRROR PITCH
- 26 X AXIS
- 28 Y AXIS
- 30 CENTER (OF MIRROR 14)
- 50 DISTRIBUTE UNIFORMLY OPERATION
- 52 FIRST DECISION OPERATION
- 54 DISTRIBUTE SYMMETRICALLY OPERATION
- 56 SECOND DECISION OPERATION
- 25 58 GROUP TOWARD CENTER OPERATION

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MIRROR CONTACT PATTERN FOR A DISPLAY DEVICE

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TECHNICAL FIELD

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The present invention relates to the field of integrated circuit manufacture, and more specifically to an improved method and construction for the manufacture of light reflective liquid crystal display ("LCD") arrays. The predominant current usage of the present inventive improved mirror contact pattern is in the construction of reflective LCD arrays for projection display devices, wherein it is desirable to keep the surface of the array as flat and flawless as possible.

TECHNICAL FIELD

BACKGROUND ART

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In the construction of light reflective LCD arrays it is necessary to make some electrical connection between the circuitry thereof and the actual reflective surface. The accepted practice for accomplishing this purpose is to provide conductive "vias" through an insulating layer which separates the mirrors from the underlying circuitry layers. Studies have shown that, despite the best known manufacturing techniques, there is a minute perturbation or distortion, in the form of dimples, of the mirror surface where the vias contact the mirrors.

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Unfortunately, the distortion of the mirrors caused by the vias can result in visibly perceptible distortion of an image produced by the LCD array. It would be desirable to have some method or means to eliminate, or at least reduce, the perceptible effects of such physical distortion of the mirrors. However, to the inventor's knowledge, although this problem is known in the prior art, there has been no practical solution for the problem.

DISCLOSURE OF INVENTION

Accordingly, it is an object of the present invention to provide a method and apparatus for minimizing the perceptible effects of distortion caused by via contact with the mirrors in a reflective LCD array.

It is another object of the present invention to provide a method and apparatus for improving the quality of an image produced by a reflective LCD array.

It is yet another object of the present invention to provide a method and apparatus for producing a reflective LCD array which can be readily implemented using known manufacturing techniques.

Briefly, a known embodiment of the present invention is an arrangement of vias in a reflective LCD array such that overall distortion of the mirror surface is kept to a minimum, and further such that what distortion remains is less offensive to the eye than some alternative placements might be. In the embodiment described herein, two contact vias are placed according to several criteria for placement, which criteria are intended to cause the resulting mirror surface to tend toward the above stated objectives.

These and other objects and advantages of the present invention will become clear to those skilled in the art in view of the description of modes of carrying out the invention, and the industrial applicability thereof, as described herein and as illustrated in the several figures of the drawing. The objects and advantages listed are not an exhaustive list of all possible advantages of the invention. Moreover, it will be possible to practice the invention even where one or more of the intended objects and/or advantages might be absent or not required in the application.

Further, those skilled in the art will recognize that various embodiments of the present invention may achieve one or more, but not necessarily all, of the above described objects and advantages. Accordingly, the listed advantages are not essential elements of the present invention, and should not be construed as limitations.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a cross-sectional, side elevational view of a portion of an example of a reflective LCD array, according to the present invention;

Fig. 2 is a top plan view of a portion of the reflective LCD array of Fig. 1;

Fig. 3 is a top plan view of a portion of another embodiment of the inventive reflective LCD array;

Fig. 4 is a top plan view of a portion of yet another example of the inventive reflective LCD array; and

Fig. 5 is a flow diagram depicting the present inventive method for placing vias in a LCD array.

DETAILED DESCRIPTION OF THE INVENTION

The embodiments and variations of the invention described herein, and/or shown in the drawings, are presented by way of example only and are not limiting as to the scope of the invention. Unless otherwise specifically stated, individual aspects and components of the invention may be omitted or modified, or may have substituted therefore known equivalents, or as yet unknown substitutes such as may be developed in the future or such as may be found to be acceptable substitutes in the future. The invention may also be modified for a variety of applications while remaining within the spirit and scope of the claimed invention, since the range of potential applications is great, and since it is intended that the present invention be adaptable to many such variations.

Fig. 1 is a diagrammatic (not to scale) cross-sectional, side elevational view of a small portion of an example of a reflective LCD array, according to the present invention, which is designated therein by the general reference character 10. A metal (circuitry) layer 12 is connected to a plurality (six are shown in this example segment) of mirrors 14 by a plurality of vias 16. The vias 16 pass through an insulating layer 18, and a clear protective layer 20 is over the mirrors 14. One skilled in the art will

recognize that this is not an exhaustive list of the components of the reflective LCD array 10. For example, in most applications there will be at least some additional metal layers 19 and display driver circuitry layers (not shown in detail) below the metal layer 12. However, the portions of the reflective LCD array 10 which are relevant to the present invention are shown in the view of Fig. 1.

It will be noted that, in the example of Fig. 1, two vias 16 per mirror 14 are shown. In the prior art it has been common to use only one via 16 per pixel. While the inventor believes that the use of two vias 16 per mirror 14 will be effective for practicing the present invention, it should be recognized that the present invention is not limited to the use of two vias 16 per mirror 14, and other quantities of vias 16 could be used, according to the principles described herein, to practice the invention. Indeed, in the example of the reflective LCD array 10 shown, both of the vias 16 are used as electrical conductors. However, it is within the scope of the invention that "dummy" vias (not shown) could be used, again according to the principles described herein, to practice the invention.

Fig. 2 is a top plan view of an example of the reflective LCD array 10. In the view of Fig. 2 the vias 16 are visible through the mirrors 14, and the clear protective layer 20 (Fig. 1) cannot be seen. According to the example of Fig. 2, the vias 16 are placed along a diagonal of the generally square mirrors 14. The spacing (X) 22 of the vias 16 is related to the pitch (P) 24 of the mirror 14 layout according to the following formula:

$$X = \frac{P * \sqrt{2}}{2}$$

Those skilled in the art will understand that the pitch (P) is defined as the distance between corresponding features of adjacent cells.

According to the example of the placement of the vias 16 shown in the example of Fig. 2, the vias 16 are uniformly spaced across the mirror surface of the reflective LCD array 10 and, further each mirror 14 has an identical (or as nearly identical as possible) arrangement of the vias 16. Because the spacing (X) of the vias 16 under each mirror 14 is determined according to the above formula, and because the vias 14 are arranged symmetrically about the center, and on a diagonal of the mirror 14, the spacing (W)

between diagonally adjacent vias 16 of adjacent mirrors 14 is the same as the spacing (X) between vias 16 of each mirror 14. Distances (X) and (W) do not appear equal in the drawings, because the pixel mirrors 14 and the gaps therebetween are not drawn to scale. The inventor has found that such an arrangement is most desirable, since the eye readily detects regular, unequal spacing (not shown) of the vias 16 as a phenomenon known as "banding". Indeed, as will be discussed in more detail hereinafter, even random irregularity is preferable to regular uneven spacing in this respect.

As can be seen in the view of Fig. 2. The vias 16 are spaced such that they are equidistant from an X axis 26 and also from a Y axis 28 of each individual mirror 14. However, the vias 16 are not symmetrical about the X axis 26 and the Y axis 28, in that a reflected image of the via 16 would not produce an identical pattern. The term "axis" herein is used in the sense of being relative to the X or Y axis of a two dimensional graphical layout. That is, the X axis 26 and Y axis 28 lie on a plane which is the surface of the mirrors 14 and each is perpendicular to the sides of the generally square mirrors 14.

It should be noted that while the arrangement of the vias 16 shown in the example of Fig. 2 is ideal for accomplishing the one purpose of providing the most regular and uniform mirror 14 surfaces available using two vias 16 per mirror 14, it may not be possible or practical to use such an arrangement. For example, one skilled in the art of chip layout will recognize that alternate mirrors 14 may have associated circuitry which is "mirrored" or reflected. That is every other mirror 14 may have identical circuitry there beneath, while alternate mirrors 14 may have circuitries which are alike to each other, but which are the reflected images of that on either side thereof. Under such circumstances, using the diagonal layout of the example of Fig. 2 would result in a regular asymmetry which, as described above, is a most undesirable condition.

Fig. 3 is a top plan view of another example of a reflective LCD array 10a, according to the present invention, showing an alternate arrangement of the vias 16. As can be seen in the view of Fig. 3, the vias 16 in this example have a mirror spacing (X1) 22a along the Y axis 28 which is $\frac{1}{2} P$, while the vias 16 are centered in the mirrors 14 along the X axis. This layout does not provide for as uniform a layout of the vias 16

as is shown in the example of Fig. 2, as the spacing is closer along the Y axis as compared to that along the X axis. However, it will be noted that the example of Fig. 3 does provide for symmetrical arrangement of the vias 16 along the X axis 26 and also along the Y axis 28. This prevents the undesirable banding effect discussed above.

Also, it will be noted that "mirroring" of alternate mirror 14 cells is acceptable, since mirroring the arrangement of vias 16 shown in Fig. 3 will result in an identical arrangement. It should be noted that, in this example as in all of the examples discussed herein, the vias 16 are evenly spaced about a center 30 of the mirror 14, where this is possible and practical.

Fig. 4 is a top plan view of yet another example of a reflective LCD array 10b, according to the present invention. In the example of Fig. 4 it can be seen that the vias 16 are centered in the mirrors 14 along the Y axis (as in the example of Fig. 3). However, in the example of Fig. 4 the vias 16 are placed close together and near the centers 30 of the mirrors 14. The example of Fig. 4 illustrates the principle, according to the present invention, that the vias 16 may be grouped closely together near the center of the mirrors 14 to produce a generally uniform distortion of the mirrors 14. That is, where only a single via 16 per mirror 14 is used, the best place to put that via 16 would be at the center of the mirror 14, thereby providing for symmetry along both the X axis 26 and the Y axis 28. Similarly, where a plurality (two, in the present example) of vias 16 are grouped together near the center of the mirror 14, then a single distortion near the center of the mirror 14 will be produced, thereby providing the desired symmetry along the X axis 26 and the Y axis 28 even though the vias 16 are not uniformly distributed on the mirrors 14.

Fig. 5 is a flow diagram depicting an example of the present inventive method for placing the vias 16 on the reflective LCD array 10. As previously discussed herein, if possible and practical, the vias 16 should be distributed uniformly on the reflective LCD array 10 such that the extremes of peaks and valleys of the dimples on the surface of the mirrors 14 will be minimized. This is because the more uniform the spacing of the vias 16, the smaller will be the largest space therebetween, wherein a dimple might form. This is accomplished (experimentally) in a distribute uniformly operation 50. In a first decision operation 52 it is determined if this arrangement is possible and practical,

considering the underlying circuitry as discussed previously herein. If it is both possible and practical, then the operation is ended, and the arrangement is accepted. If not, then positioning the vias 16 symmetrically on both the X axis 26 and the Y axis 28 is considered in a distribute symmetrically operation 54. As discussed previously herein, the vias 16 can be placed symmetrically on the X axis 26 and also symmetrically on the Y axis 28, even though the spacing of the vias 16 may be different along the X axis 26 than along the Y axis 28.

In a second decision operation 56 it is determined if the arrangement according to the previous operation is both possible and practical. If not, the vias 16 can be grouped toward the center 30 on one (preferably) or both (if necessary) axis 26 and 28 in a group toward center operation 58.

Various modifications may be made to the invention without altering its value or scope. For example, quantities and/or placement of the vias 16 can be different from the examples show while keeping the spirit of the invention according to the inventive method described.

All of the above are only some of the examples of available embodiments of the present invention. Those skilled in the art will readily observe that numerous other modifications and alterations may be made without departing from the spirit and scope of the invention. Accordingly, the disclosure herein is not intended as limiting, and the appended claims are to be interpreted as encompassing the entire scope of the invention.

INDUSTRIAL APPLICABILITY

The inventive reflective LCD array 10 is intended to be widely used in the production of video imaging devices, particularly where the size and/or criticality of the display requirements call for minimal distortion and optimal image clarity and resolution. According to the present invention, a plurality of vias 16 are positioned in a manner to solve the problem of distortion caused by the vias. The present invention does not address the problem of the physical distortion caused by the vias 16. Rather, the

invention assumes that manufacturing techniques will be optimized to minimize such physical distortion. Instead, the present invention operates to minimize the perceived effect of any such residual distortion.

Since the reflective LCD arrays 10 of the present invention may be readily produced using known manufacturing methods and operations, and since the advantages as described herein are provided, it is expected that it will be readily accepted in the industry. For these and other reasons, it is expected that the utility and industrial applicability of the invention will be both significant in scope and long-lasting in duration.

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